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Design of an
Interlocking Plant

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DESIGN OF AN INTERLOCKING PLANT

BY

FRED AUGUSTUS COX

THESIS

FOR

DEGREE OF BACHELOR OF SCIENCE

IN

CIVIL ENGINEERING

COLLEGE OF ENGINEERING

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May 25, 1907.

This is to certify that the following thesis prepared under the immediate direction of Mr. R. B. Slippy, Instructor in Civil Engineering, by

FRED AUGUSTUS COX

entitled DESIGN OF AN INTERLOCKING PLANT

is accepted by me as fulfilling this part of the requirements for the Degree of Bachelor of Science in Civil Engineering.

Ira O. Baker

Head of Department of Civil Engineering

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Introduction.

Grade crossings afford a fruitful source of accident and delay to railway traffic. In order to insure the safety of the traveling public, the laws of many states require that all trains shall come to a full stop within a distance of from 300 to 600 feet from a grade crossing. To prevent the delay and expense of stopping trains where the traffic is large, the crossing is often provided with a set of signals and derailing switches, operated by levers placed in a tower which is situated so as to command a good view of the tracks. These levers are interlocked in such a manner that they can only be operated in a certain sequence, making it impossible to admit conflicting trains to the crossing. Such a system of signals, switches, and derails is called an interlocking plant. When double track crossovers, turn-outs from the main line or a Y connecting the intersecting tracks, occur within the limits of the interlocking plant, the switches are operated by levers, placed in the tower. These levers are interlocked with the levers controlling the signals and derail of the crossing. The object of this thesis is to design an interlocking plant for the crossing of the Illinois Central with the Big Four and Wabash railroads at Champaign, Illinois and to determine the cost of installing and operating it. Before taking up the design, the economic value of the plant to the railway companies interested will be determined.

Value of the Interlocking Plant.

The value of the plant may be determined by considering the cost of stopping the trains at the crossing. A. M. Wellington, in "The Economic Theory of the Location of Railways", estimates the cost of stopping a train to be from thirty to sixty cents. If the crossing were on a grade so steep that the size of the trains would be reduced on account of the stop, an additional item of cost would be involved, but, as the grade at this crossing is slight, being about 0.17 per cent on the Illinois Central and 0.10 per cent on the Big Four and the Wabash, this item may be neglected. The crossing is close to the Illinois Central depot and yards, therefore, the trains on that road always cross at a greatly reduced speed. This would reduce the cost of stopping their trains. On the other hand the weight of the Illinois Central trains is more than twice that of the Wabash and Big Four trains which are probably about the average for which the Wellington estimates were made. Considering that the extra weight of the Illinois Central trains will equal the saving in cost due to the decreased speed, we may assume that the cost of stopping the Illinois Central trains is the same as that for the other roads. In order to make a conservative estimate the minimum cost given by Wellington, which is thirty cents per train will be used.

The average number of trains on each road is as follows:- on the Illinois Central, fifteen freight and seven passenger trains each way, or a total of forty four trains; on the Big Four, six freight and four passenger trains each way or a total of twenty trains; on the Wabash, one passenger and two mixed

trains each way or a total of six trains. This makes a grand total of seventy trains per day. The cost of stopping seventy trains at thirty cents each is $21.00 per day. The cost of operating the plant will be assumed as follows:- two signal men at $2.00 per day, one man at $1.50 per day to care for the electrical apparatus, expenses including power, fuel, light, repairs, etc. $1.50 per day making a total daily cost of $7.00 per day. Since the total saving effected by the plant is $21.00 per day and the cost of operation is $7.00 the net saving will be $14.00 per day. In one year $14.00 per day will amount to $5110.00. The amount which the railway companies would be justified in expending to install an interlocking plant will be a sum such that the net annual saving will pay the interest at the rate of five per cent, and in addition provide a sinking fund sufficient to replace the plant by the time it is worn out.
At four per cent compound interest a principal will double itself in eighteen years. Assuming that the machinery will last that long the annual depreciation will be four per cent of the principal. With interest at five per cent the annual interest and depreciation will be nine per cent of the allowable investment. Since this is equal to the net annual saving which is $5110.00 the value of the plant or the allowable investment will be $56,778.00. The cost will be taken up in connection with the design but for the present it may be assumed that it will not be more than $20,000.00. A comparison of these figures will show that the installation of the plant will result in a saving of $36,778.00 per year which clearly demonstrates that it will

be advisable to install the plant.

Type of Plant.

According to the motive power used in operating the signals and switches, interlocking plants may be classified as mechanical, electric, pneumatic, electro-pneumatic, and hydraulic plants. Of these types, the mechanical and electrical plants are in most common use. In the mechanical type, the signals and switches are operated by wires or pipes connected to the levers in the tower. In the electrical type each switch or signal is attached to a motor, and the movement of the lever in the tower closes a circuit between the motor and a storage battery. The current from the storage battery turns the motor through a certain number of revolutions producing the desired movement of switch or signal.

The principal advantage of the mechanical type is cheapness of first cost. No engine, dynamo, mortors or storage batteries are required as with the electrical type. On the other hand, with the electric type the signals and switches may be operated at greater distances, and with more ease than with the mechanical plant. It is also possible to connect two or more motors in one circuit and operate them with one lever, reducing in this way the number of levers. In general it may be said that for crossings having light or moderate traffic, and a system of tracks and switches which is not too complicated, the mechanical plant is the most economical. However, when the traffic is heavy and the system of tracks complicated the operation of a

mechanical plant will require the services of two men whereas an electrical plant doing the same work could be operated by one man.

On the crossing to be controlled by the proposed plant, the traffic is heavy, averaging seventy trains per day. In addition to this there are twelve Illinois Central per day that pass around the Y between the Illinois Central and the Wabash tracks. A large number of switch engines also pull back and forth from one part of the yard to another. A mechanical plant at this crossing would require two signalmen and an electrical plant only one. Thus the cost of operating the electrical plant will be $4.00 per day less than the cost of operating the mechanical plant. In one year this would amount to $1,460. Assuming that it will cost $5,000.00 to install a mechanical plant, and $20,000.00 to install an electrical plant, the difference in cost is $15,000.00. Taking interest at five per cent per annum and depreciation at four per cent per annum, the annual saving necessary to pay for the increased cost is $1,350.00. Since the annual saving is $1,460.00 it will be more economical to install an electrical interlocking plant.

Arrangement of Switches and Signals.

The tracks, turnouts, and crossovers within the limits of the plant are shown in plate I. In addition to the signals and derails used to protect the crossing, all the crossovers and turnouts from the main lines within these limits, except the turnouts to tracks 4 and 5 and the turnout to track 15, will be controlled. The control of these switches will give greater security to the crossing and will also facilitate the movement of trains at this point. Tracks 4, 5, and 15 are spur tracks and are seldom used. The advantage of having them under control is not deemed of sufficient importance to justify the additional expense.

The arrangement of switches and signals is shown in plate II. The levers of the interlocking machine are numbered to correspond to the switches and signals which they operate. When the levers are at the normal position all the signals are set at danger, all the derails are open, and all the switches are closed. When a train approaches the switches and signals governing the desired route, are cleared. The levers are interlocked so that they may be reversed only in a sequence, making it necessary to close the derail before clearing the home signal; also, to clear the home signal before the distant signal. The levers are also interlocked in the reversed position, the sequence in which they are thrown to normal being usually opposite to that in which they are reversed. The distant signal is brought to danger before the home signal, and the home signal is returned to danger before the derail is opened. When any

route is cleared the levers of that route in the reversed position lock the levers of conflicting routes in the normal position.

The sequence in which levers are reversed to clear the different routes is shown by the manipulation chart, and the locking performed by the levers in their reversed position is indicated by the locking sheet. In the locking sheet a circle around any number indicates the reversed position of the lever. The normal position is indicated by the number without the circle. To determine the locking performed by any lever in its reversed position, look up the number in the first column of the locking sheet and the number following in the same horizontal line indicate the levers locked. Thus, see table II, line 1, 1 locks 2 reversed and 2 locks 3 reversed and 4 either reversed or normal. Suppose it is desired to clear the track for a south bound Illinois Central train. Referring to plate II, that portion of the south bound Illinois Central track north of the crossing is designated as M and the part south of the crossing is marked C. In the manipulation chart from M to C the levers are 30-3-2-1. This shows the levers to be reversed and also the sequence in which they must be thrown. Referring to the locking sheet it is seen that 30 reversed locks 3 reversed, also 2 locks 3 reversed and 1 locks 2 reversed. Therefore in returning the levers to the normal position the order in which they are thrown will be 30-1-2-3. Again referring to the locking sheet it may be seen that three reversed locks 14, 8, 17, 29, 33, 35 and 7 all normal. In other words when this track is cleared the levers of all conflicting routes are locked in the normal

position. This arrangement is necessary in order to prevent a careless or inexperienced operator from throwing a switch in front of a moving train. It may sometimes be desirable, however, to reverse lever 8, opening the turnout switch to track E plate II, when the derail lever 3 is reversed. Suppose for instance that on the approach of a south bound train the route from M to C is cleared, and when the train reaches the tower it is discovered that they wish to pass to track E. If there were no way of releasing the lever 8, it would be necessary for the train to back up beyond the home signal before the switch could be thrown. The arrangement by which the release of lever 8 is effected is as follows:- a vertical shaft is raised by means of a slow motion screw. This shaft is so arranged that when the screw is turned through about twenty revolutions, the upper end of the shaft lifts a catch out of a notch in lever 8, in this way releasing the lever. This arrangement will prevent hasty action on the part of the operator by compelling him to give time and thought to releasing the lever.

All switches and derails are provided with detector bars to prevent the switches from being thrown while a train is passing. A detector bar, see fig. 3 plate IV, consists of a flat bar, A, about 50 feet long, which is held in position against the outside of the railhead by links B, pivoted to clips C, which are attached to the rail as shown in the end elevation. The bar is attached to the switch movement so that before the switch can be thrown the bar must be moved about eight inches in a horizontal direction. Since the links are pivoted at their lower

ends the bar, at the middle of its stroke is raised about one inch above the rail head. If a car wheel is above the bar it is evident that the bar cannot be thrown. The detector bar is interlocked with the switch machine so that, until the bar is thrown, no movement of the switch can take place.

Detector bars are also provided at the crossing as shown in plate II. The six detector bars at the crossing of Wabash and the Illinois Central are attached to a motor located northeast of the crossing. The arrangement by which the detector bars are attached to the motor is shown in plate III. The six detector bars at the crossing of the Big Four and the Illinois Central are connected to a motor located northwest of this crossing. These two motors are connected in the same circuit and this circuit is controlled by lever 30 of the interlocking machine. Referring to the manipulation chart it may be seen that in order to clear any of the main line routes it is necessary to reverse lever 30 before closing the derail in that route; also in returning the route to the normal position lever 30 must be thrown to the normal before the derail levers, since, as shown by the locking sheet lever 30 in the reversed position locks the main line derail levers in the reversed position. Since the detector bars are thrown when lever 30 is reversed and also when it is returned to normal it is obvious that when there is a train on the crossing none of the main line derails can be either opened or closed. This arrangement makes it impossible to clear a conflicting route while a train is on the crossing.

The signals used are of three kinds home, distant and

dwarf signals. The home signals No. 10, 16 and 28 plate II are one arm semaphore signals consisting of a blade or arm pivoted to an iron post. The height of the post is such that the center of the blade is about 30 feet above top of the rail. The blade is a thin piece of board about five feet long tapering in width from about ten inches at the outer end to seven inches near the post. The face of the blade is painted red and the back is painted white. To indicate danger the blade makes an angle of 90 degrees with the pole, and to give the clear signal the blade is dropped until it makes an angle of only 15 degrees with the post. At night the danger signal is given by a red light and the clear signal by a green light. A lamp is attached to the post by means of a bracket, and the arm plate, (i.e. the casting by which the semaphore blade is attached to the post), carries colored glasses called spectacles which are moved so that the glass of the proper color is brought in front of the lamp for each position of the signal blade.

The home signals numbered 2, 18 and 22 are two arm semaphores, the upper blade being used for the main line and the lower blade for the turnout. The distance from center to center of semaphone arms is six feet and the upper arm is about 36 feet above top of rail. The size and color of the signal blades, and the arrangement of the colored lights for night signals is the same as with the one arm semaphores described above.

The distant signals numbered 1, 15, 21, and 27 are one arm semaphores similar to the home signals, except, that the

blades are painted yellow on the face and have their ends notched or fish tailed whereas the ends of the home signals are square. The distant signal is used to indicate the probable position of the home signal. The horizontal position of the blade indicates to the engineman that he must bring his train under control and be prepared to stop at the home signal if it is found to be at danger. For this reason a yellow light indicating caution is used to correspond to the horizontal position of the blade instead of the red light indicating danger which is used with the home signal. As with the home semaphore the clear signal is given by a green light.

All the signals used in this plant, except the above described home and distant signals, are used for slow movements and are dwarf signals. A dwarf signal has a blade about one foot long with a square end painted red on the face and white on the back. The blade is pivoted to a low post, the center of the blade being about two and a half feet above top of rail. The dwarf signal is often used in yards close to the track and between tracks. For this reason the blade, when in the horizontal position, is in danger of being struck by a passing object and broken. To guard against this the blade is hinged to the arm plate and provided with a spring which holds the blade to its proper position but allows it to bend when struck by a passing object. The danger signal is given by the horizontal position of the blade and the red light, the clear signal is given by the vertical blade and the green light. When a dwarf signal is used to guard a turnout switch the normal position of the signal

is at clear, since the switch is set normally to clear the main lines; but when a dwarf signal guards a derail the normal position of the signal is at danger since the derail is normally open.

A small lens is placed in the back of all signal lamps. The light from this lens passes through a blue glass when the signal blade is in a normal position. This enables the operator to see one side or the other of all signal lights and to determine the position of the signal. This also enables the operator in the tower to detect the failure of a light from any cause.

TABLE I.

Manipulation Chart.

North & West Bound Trains			South & East Bound Trains		
From.	To.	Levers.	From.	To.	Levers.
A.	B.	31,32.	N.	B.	30,11,12.
B	N.	30,11,12,10.	N.	C.	14,13,
B.	C.	35,36.	M.	C.	30,3,2,1.
C.	M.	30,3,5.	B.	A.	31,32.
C.	N.	30,3,5,14,13.	C.	B.	35,36.
C.	G.	7,6.	C.	D.	33,34.
D.	C.	33,34.	M.	E.	8,9,30,3,2,1.
E.	C.	30,8,9.	M.	L.	30,3,4,2,1.
F.	G.	26,25.	K.	L.	23,24,22,21.
G.	H.	19,20,18.	K.	J.	23,30,29,22,21.
I.	H.	19,30,17,16,15.	H.	I.	19,30,17,18.
J.	K.	23,30,29,28,27.	H.	G.	19,20,18.
L.	K.	23,24,22.	G.	F.	26,25.
L.	M.	30,3,4.	G.	C.	7,6.

TABLE II.

Locking Sheet.

① — ②.
② — ③ — ④ — 4.
③ — 14 — 8 — 17 — 29 — 33 — 35 — 7.
④ — ③.
⑤ — ③.
⑥ — ⑦.
⑦.
⑧ — 7 — 20
⑨ — ⑧.
⑩ — ⑪.
⑪ — 14 — 31 — 35 — 17 — 29.
⑫ — ⑪.
⑬ — ⑭
⑭
⑮ — ⑯.
⑯ — ⑰.
⑰ — ⑲ — 3 — 11 — 20.
⑱ — ⑲ — ⑳ — 20 — 16.
⑲.
⑳.
㉑ — ㉒.
㉒ — ㉓ — ㉔ — 24 — 28.

TABLE II.

Locking Sheet.

㉓
㉔
㉕—㉖
㉖
㉗—㉘
㉘—㉙
㉙—㉓—3—11—24
㉚—③—⑪—⑰—㉙
㉛
㉜—㉛
㉝
㉞—㉝
㉟
㊱—㉟

Description of Machinery.

In ordering an interlocking machine it is customary to provide the manufacturers with a diagram similar to plate II, showing the switches and signals numbered to correspond to the levers which operate them; also with a locking sheet and a manipulation chart. This information enables the manufacturers to work out the details by which the levers are interlocked. A brief description of the interlocking machine, also of the switch and signal machines will now be given. The interlocking machine used is that of the Taylor electric system. It consists of a cabinet and frame for 40 levers, 36 levers and 4 blank spaces. The cabinet and frame is shown in fig. 2, plate IV. The levers are straight steel bars with handles at right angles, drawn toward the operator for the reversed position. Each lever is connected with a circuit closer on the switch or signal circuit, and the levers are interlocked mechanically. The switch machine is worked by a motor of one horse power. In closing the switch the lever on the interlocking machine is pulled a half stroke which closes the circuit and causes the motor A fig. 1 plate IV, to turn through twenty revolutions in about two seconds driving the train of gear wheels shown at B. By means of this gearing the main driving wheel is revolved through one revolution. By means of a crank pin and cam movement, M, this wheel drives the rod connecting with the switch points. This wheel is also attached to the drive wheel N, which operates the lock, pole changer and detector bar. The initial movement of the drive wheel throws

the detector bar by means of the rod O and unlocks the switch by with drawing the lock bar P from a slot in the lock rod K. After the switch is thrown the rod N moves back to its original position throwing the detector bar and relocking the switches. When the lock bar P is driven back into the slot, unlocking the switch, it operates the pole changer at D. As soon as the motor circuit is broken and the armature connections reversed the motor begins to act as a generator setting up a counter electro motive force which opposes its own momentum and also sends an indication current back to the interlocking machine. The indication current actuates electro magnets on the interlocking machine which release the lever and enable the operator to finish the stroke. If for any reason the switch is not moved fully home the lock bolt is obstructed, there is no indication, and the inability to complete the stroke of the lever shows that the switch is out of adjustment.

The signal machine is operated by a motor of one sixth horse power placed on a bracket pastened to the pole about three feet from the ground. The semaphore arm is provided with a counter weight which holds the blade normally in the horizontal position. To bring the signal from the normal or danger to the clear position the motor turns a drum which winds up a chain, and lifts the weighted end of the balance lever, throwing the semaphore arm down. As soon as the signal reaches the clear position a pole changer is operated closing the circuit through a brake magnet which holds the signal in position and opens the main circuit to the motor. The pressure

generated by the motor sends a current for the indication back to the tower the same as with the switch machine. To return the signal to the normal position the electro magnet brake is de-energized and the counter weight pulls the blade to the horizontal position. As the blade swings up to this position it operates a circuit closer which returns an indication current to the tower. The indication current operates an electro magnet which works a releasing latch on the lever permitting the stroke to be completed. In operating any switch or signal the first movement of the lever is only a partial stroke. Without the indication the full stroke of the lever and the release of conflicting levers cannot take place.

Both blades of the two arm semaphores, numbered 2, 22, and 18 plate II, are operated by one lever. The signal arm operated by the movement of the lever depends upon the position of the turnout switch. The device by which this arrangement is affected is called a selector. The counter weight of each signal is attached to a hook ended bar. Each bar is provided with an electro magnet which, when energized, causes the hook to become attached to the driving chain. The circuits are so arranged that when the switch is closed the magnet controlling the upper signal blade is energized, and conversely, when the switch is open the magnet controlling the lower blade is energized. In this way the two signals are both operated by the same lever and the proper signal for the position of the switch is automatically selected.

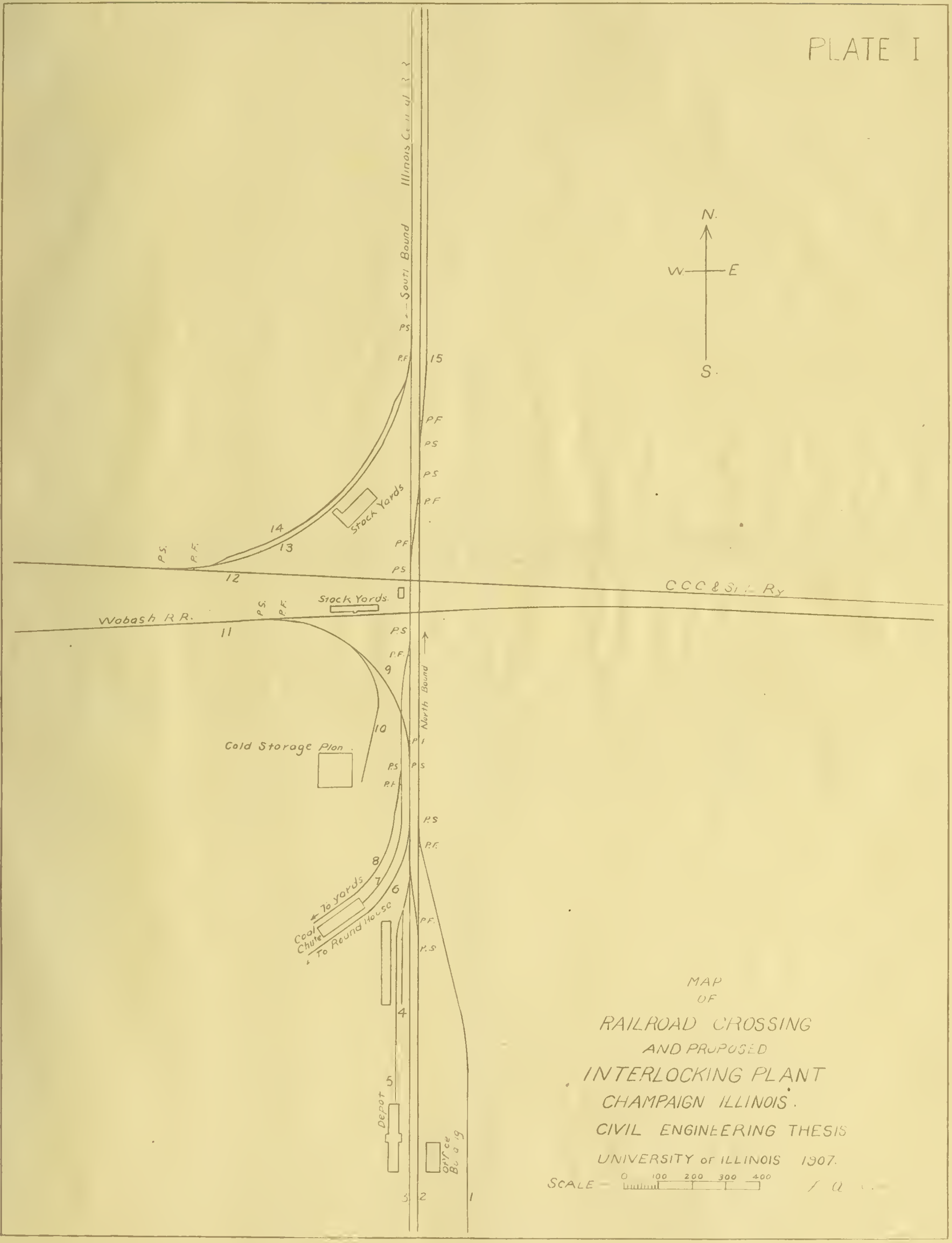
Estimate of Cost.

5 H.P. Gasoline Engine	$500.00
Dynamo	480.00
Storage Battery	302.50
Interlocking Machine	2026.00
24 Switch Motors at $160.00 each	3840.00
22 Switch Machines at $160.00 each	3560.00
Connections for 22 Switches at $40.00 each	880.00
35 Detector bars at $7.20	252.00
11 Derails at $24.00	264.00
7 High One Arm Signals at $327.40	2291.00
3 High Two Arm Signals at $454.80	1364.40
12 Dwarf Signals at $173.10	2077.40
10 Crank Stands with T Cranks at $4.50	45.50
2 Crank Stands with Right Angle Crank at $2.85	5.70
150 feet pipe at $.10	15.00
24 Pipe Carriers at $1.10	26.40
9100 feet Trunking at $.10	91.00
1000 Stakes at $.30	300.00
17 Junction Boxes at $2.00	34.00
16250 feet No. 12 Insulated Wire at $.02	325.00
13000 feet No. 10 " " at $.025	260.00
Tower 12' X 16' X 20' = 3840 cu. ft. at $.10	384.00
Installation	300.00
Total Cost	$19624.20

The prices given in the preceeding estimate were taken from the catalogue of the General Railway Signal Co. It is probable that for a plant of this size a considerable reduction from the list price could be obtained. However, in order to make a conservative estimate, no discount has been assumed. Assuming the cost of operating the plant at $5.50 per day and the cost of maintemance at $1.50 per day, also the annual interest at five per cent and the annual depreciation at four per cent, the following statement will give the annual saving effected by the plant.

Cost of Operation per annum	$2007.50
Cost of Maintenance per annum	547.50
Interest per annum	981.21
Depreciation per annum	784.97
Total Cost per annum	$4321.18
Gross Saving	7665.00
Net Saving	$3343.82

PLATE I



MAP
OF
RAILROAD CROSSING
AND PROPOSED
INTERLOCKING PLANT
CHAMPAIGN ILLINOIS.
CIVIL ENGINEERING THESIS
UNIVERSITY of ILLINOIS 1907.
SCALE = 0 100 200 300 400

PLATE II

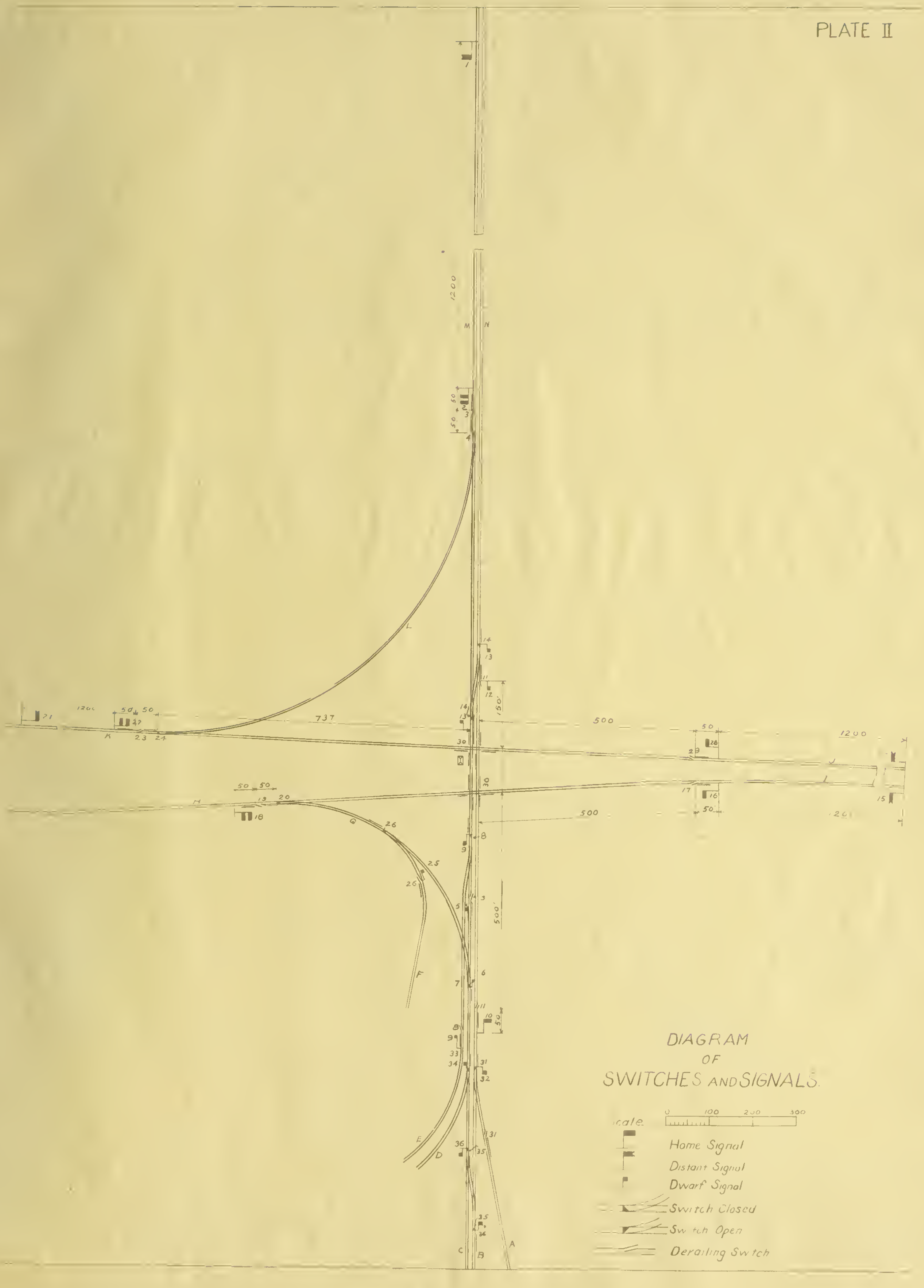
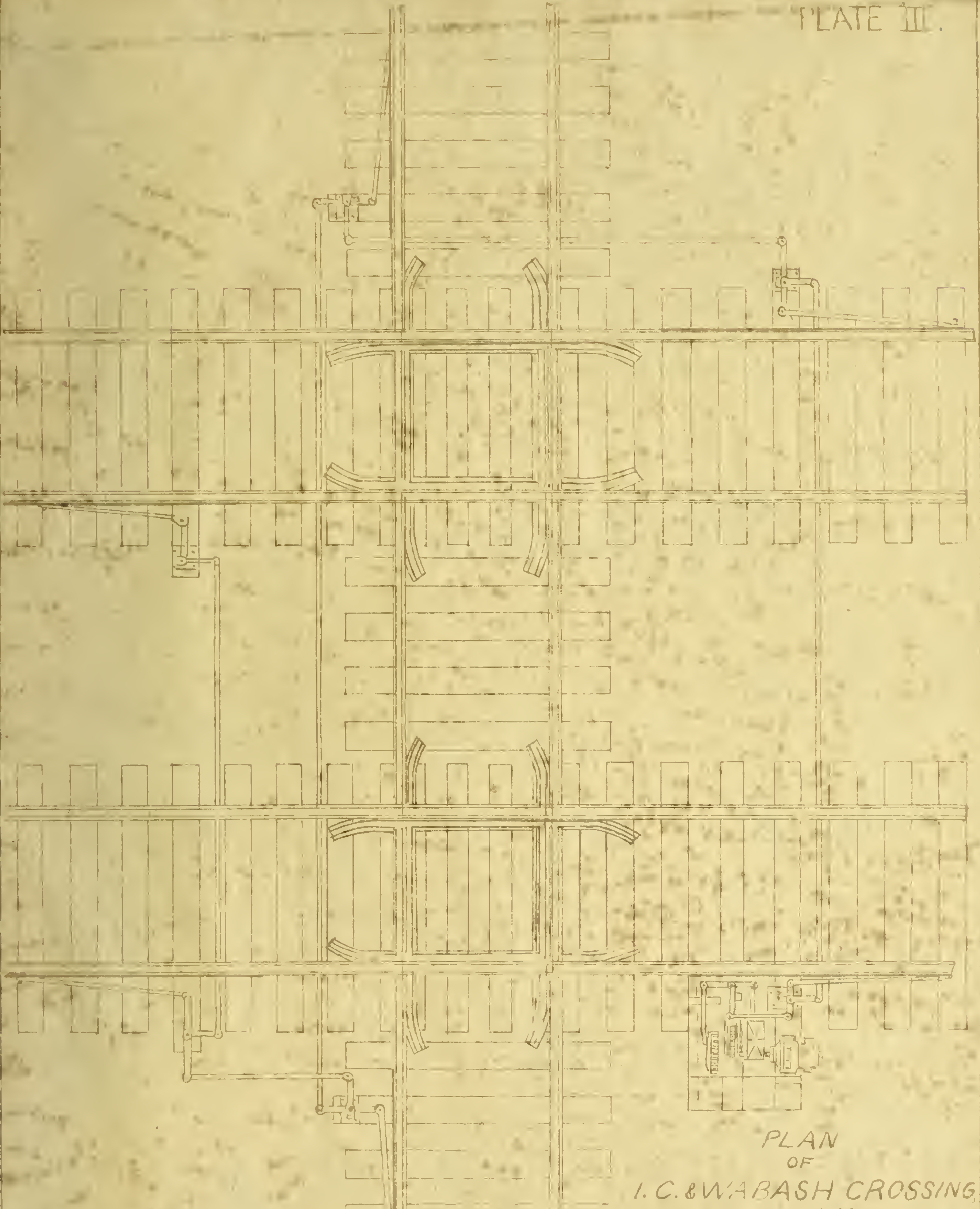


DIAGRAM
OF
SWITCHES AND SIGNALS
Scale
Home Signal
Distant Signal
Dwarf Signal
Switch Closed
Switch Open
Derailing Switch
M
N
L
K
J
I
H
G
F
E
D
C
B
A



PLAN
OF
I. C. & WABASH CROSSING,
SHOWING
METHOD OF CONNECTING
DETECTOR BARS TO MOTOR

PLATE IV.

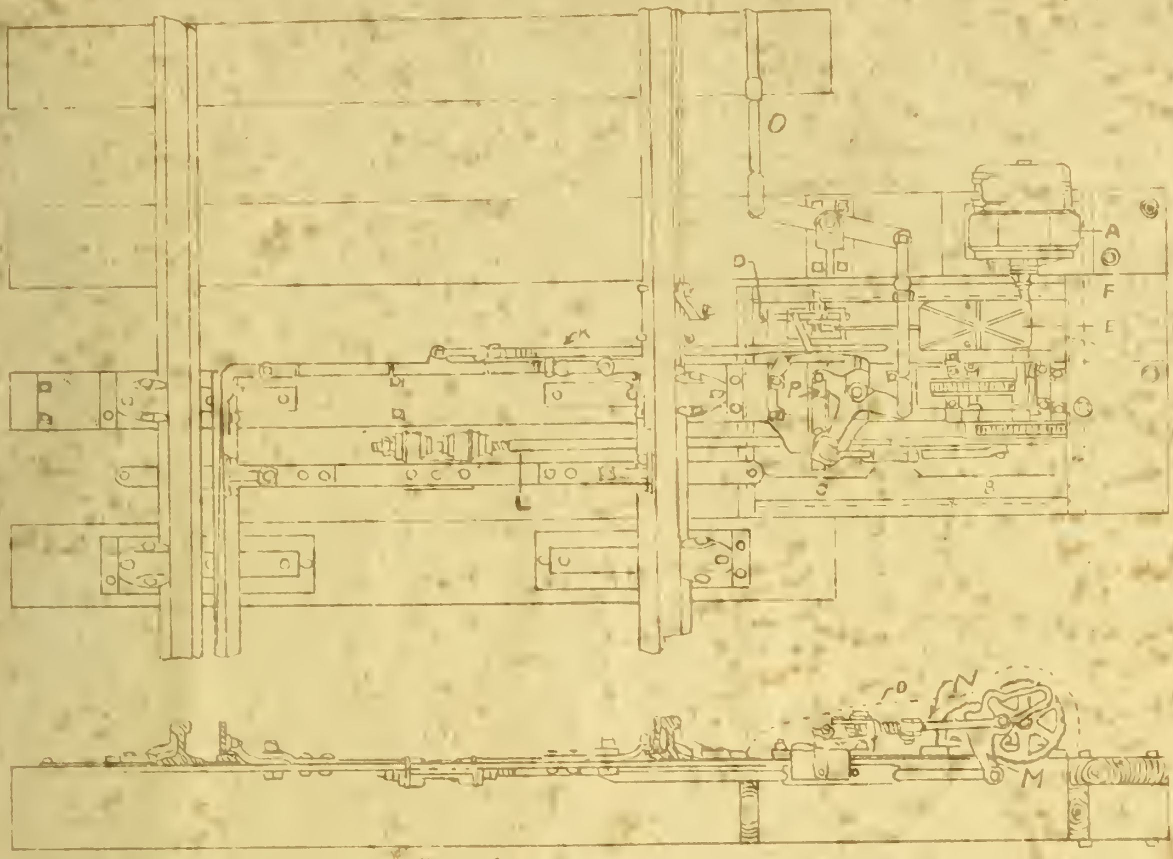


FIG. 1.

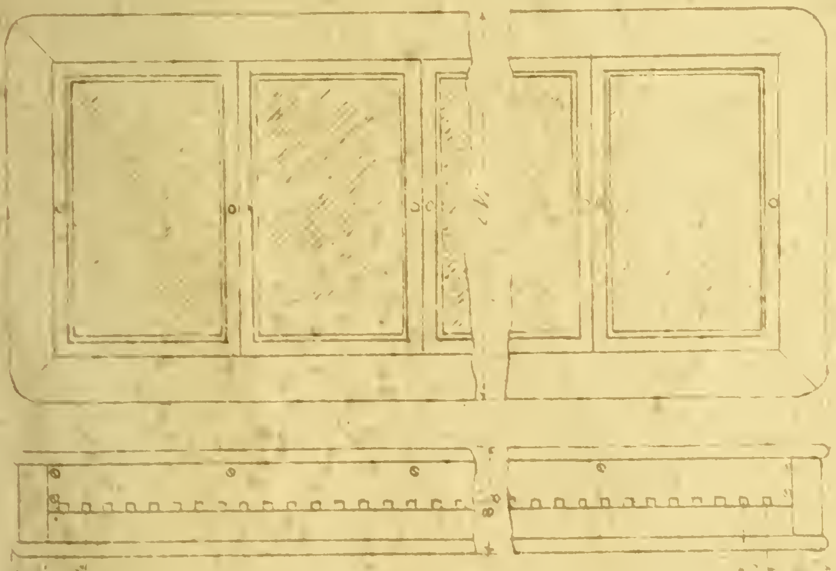


FIG 2.

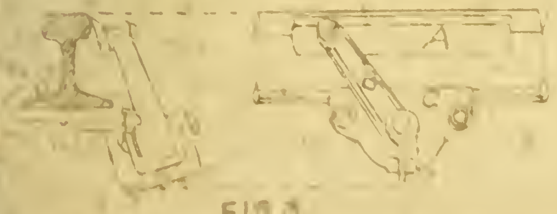


FIG 3

FIG. 4

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